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A refinement VIRIS-M-Venus Express spectral registration from the in-flight calibration

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Abstract

VIRTIS (Visible and Infrared Thermal Imaging Spectrometer) is an experiment on board the ESA mission Venus Express. The current spectral registration of VIRTIS-M (the mapping channel of VIRTIS), that defines the correspondence of the central wavelength for each band, has been evaluated from the calibration on ground. We have performed an ad-hoc study and procedure in order to check and refine it. The study is important to evaluate and eventually adjust the spectral registration due to effects of critical events, like launch and orbit insertion, and in addition to the variation as a consequence of instability of the instrument along its mission lifetime.

1. The approach

During an in-flight internal calibration of VIRTIS-M, the light coming from the internal lamp crosses a polystyrene thin layer having an absorption feature between 3.2 and 3.6 micron. The laboratory measurement of the polystyrene filter transmittance measurement, have been fitted with the in-flight measurements of the filter, the black line in Figure 2. While the laboratory data provide transmittance versus wavelength, the in-flight calibrations provide intensity in radiance ($Wm^{-2}sr^{-1}\mu m^{-1}$) versus a progressive number of band. For this reason we need to identify an empirical function for the data units conversion. The polystyrene bands envelope, of the in-flight and laboratory absorption, are then fitted using a Gaussian function for each feature and making equal the parameters. The Gaussian function is represented by the following equation:

$$f(x) = A_0 e^{\frac{-(x-A_1)^2}{2A_2^2}}. \quad (1)$$

where A_0 is the height of the curve's peak, A_1 is the position of the center of the peak, and A_2 controls the width of the curve. We can define the full width at half maximum of the Gaussian curve as:

$$FWHM = 2\sqrt{2ln(2)}A_2. \quad (2)$$

From the ratio A_{2l}/A_{2f}, where A_{2l} is the A_2 parameter for the Gaussian fit of the laboratory transmittance and A_{2f} is the same for the in-flight spectrum, we can obtain the initial guess of the spectral sampling ($nm/band$). Comparing the obtained spectral sampling, 8.9 $nm/band$ in our case, with the value measured in the laboratory before the launch, 9.47 $nm/band$,[1] we see that the values are quite close each other. From the equalization of the parameter A_0 we obtain a translation of the intensity, and from the parameter A_1 the position of the central peak. The second step is the optimization of this couple of parameters by variation of the translator factor. The pipeline used for the fit is shown in Figure 1.

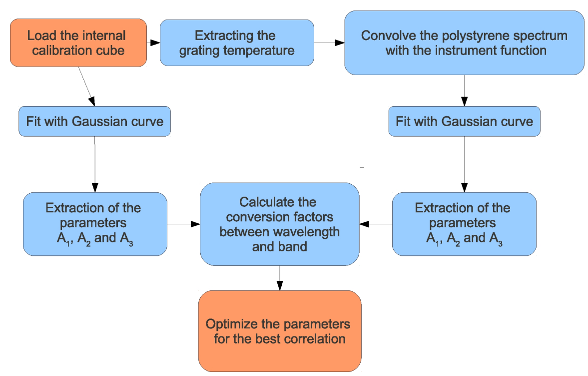

Figure 1: Pipeline for the fit of the VIRTIS-M internal calibration and the laboratory measurements.

2. Results

In Figure 2 is shown the comparison between the laboratory spectrum (black line) and the internal calibration (red line) registered using the pipeline of Figure 1 in one case. From the figure, it results that the fit of the intensity is not ideal. This is due to a different thickness of the polystyrene film used in the laboratory measurement from in-flight one and other uncertainties not considered here, related to the instrument transfer function and the optical path up the in-

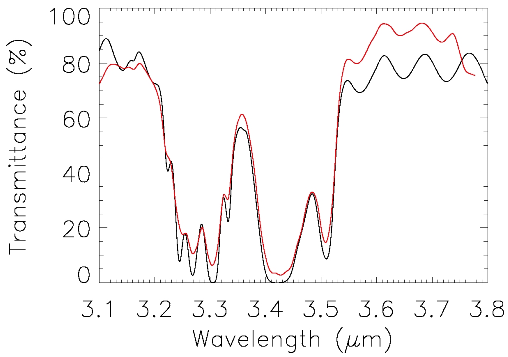

Figure 2: Comparison between the laboratory spectrum of the polystyrene and the internal calibration acquired during the orbit 142.

ternal lamp. The thickness of the filter can be evaluated from the period of the oscillations on the right side of the band, related to the Fabry-Pérot effect, and it result to be about 50 microns. The internal calibration show also a red-slope that reduce the accuracy of the fit. Nevertheless the position of the polystyrene band is satisfactory well fitted. The spectral sampling obtained after the optimization result to be 9.45 $nm/band$, very much close to the ground measurements. From Figure 2 we can extract the wavelengths

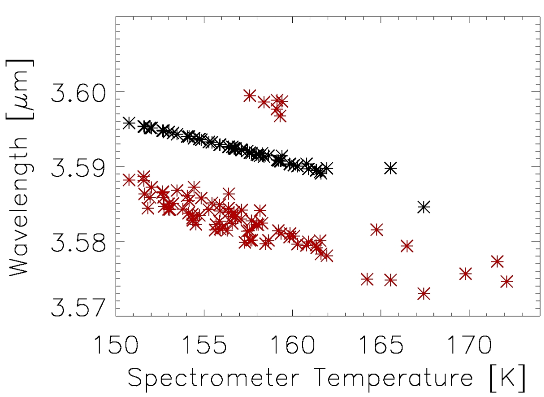

Figure 3: Wavelength variation of the band 270 with the temperature. The black asterisks are the current spectral registration, the red ones are the spectral registration obtained in this work.

corresponding to the band. Once the method is applied to all the VIRTIS-M internal calibrations executed in flight, we can extract the variation of the wavelength at a given band versus the temperature. In Figure 3 a plot of the wavelength value for the band 270 of the VIRTIS-M spectrum is shown. The black asterisks are the values of the current spectral registration, the red ones are the values obtained in this study. We can see a group of red points with a significant higher value of the wavelength. They correspond all to internal calibrations acquired during the cruise phase of the mission, that means that during the orbit insertion of the satellite something is changed in the spectral calibration of the instrument, probably due to some thermal relaxation. The differences of the other points is around 8 nm , and increases slightly with temperature. This value is close to the spectral sampling, meaning that the spectrum is roughly shifted by one band.
Using the results of the spectral registration and the methodology used for its derivation, we evaluated the full width at half maximum of the spectral profile and its variation in the thermal range in which VIRTIS-M works. The results show that the mean value is around 13 nm at 163 K with a linear dependence on temperature.

3. Conclusions

From the analysis of the results of this study is clear that the spectral registration of the infrared data of VIRTIS-VEX is changed from the measurement done on ground and the instrument conditions are changed during the Venus orbit insertion. it has to be noted that the algorithm described in this work is is self-consistent and is not performed using Venus as "calibration" target, while the results are in still in perfect agreement with the gaseous features observed in the Venus atmosphere.

References

[1] Piccioni, G. et al VIRTIS: The Visible and Infrared Thermal Imaging Spectrometer, ESA-SP-1295, ESA Publications Division, Noordwijk, The Netherlands, 2007